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HEADQUARTERS AIR MATERIEL COMMAND

WRIGHT FIELD, DAYTON, OHIO

DEPARTMENT OF ENGINEERING RESEARCH
UNIVERSITY OF MICHIGAN • ANN ARBOR

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PROJECT "WIZARD"

PROGRESS REPORT NO. 4

(October 1 - December 1, 1946)

UMR-4

Copy No. 27

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Department of Engineering Research

Ann Arbor

PROGRESS REPORT NO. 4

PROJECT MX-794
(AAF Contract W33-038 ac-14222)

Period 1 October - 1 December 1946

Project "Wizard"

S E C R E T

Emerson W. Conlon
Chairman, Department of Aeronautical Engineering

Wilbur C. Nelson
Project Engineer

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UNIVERSITY OF MICHIGAN PROGRESS REPORT NO. 4, PROJECT MX-794
(AAF Contract W33-038 ac-14222)

I PURPOSE OF PROJECT

Project MX-794 is:

(a) An eighteen months' study and engineering investigation of the guidance, propulsion, launching and aerodynamic problems culminating in a recommendation for the military characteristics and design of a supersonic guided ground-to-air pilotless aircraft capable of intercepting and destroying hostile aircraft operating at altitudes up to 500,000 ft., at speeds up to 4000 mph, at ranges sufficient to prevent damage to the defended area.

(b) A twenty-six months' basic research and engineering evaluation in the field of guidance techniques, propulsion methods, supersonic aerodynamics, servo-mechanisms, fuel chemistry, launching procedure, fusing and missile performance.

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II SUMMARY OF WORK CONDUCTED DURING THE PERIOD 1 OCTOBER - 1 DECEMBER 1946

(a) Aerodynamics

1. Preliminary performance studies of a single stage liquid rocket were completed.

2. Trajectory studies are nearing completion of liquid fuel rockets with variable burning rates and variable amounts of dry fuel rocket boost.

3. The design of the supersonic wind tunnel has been completed and an installation contract has been let.

(b) Design

1. Through a fortunate combination of circumstances it was possible to secure the services of a group of ten experienced engineers who have worked together on the design of several high performance airplanes. The group is headed by A. P. Fontaine who will be the Director of the Aeronautical Research Center at Willow Run.

2. A preliminary design study was completed of a liquid rocket with ram jet boost, in which initial acceleration of the ram jet was accomplished by means of a dry fuel rocket.

3. A preliminary design study of a single stage liquid rocket is nearing completion.

4. A design study of a multi-stage liquid rocket has been initiated.

(c) Guidance

1. A report is being prepared of existing tracking systems and tracking requirements for this project, to form a section of the Systems Planning Report.

2. The possibility of using infra-red equipment for early warning and for homing has been investigated, and this work is continuing.

3. Air borne guidance equipment circuits have been blocked out, and initial design studies made.

(d) Launching

1. Studies are being made of methods of increasing the possible ratio of fuel weight to structural weight of dry fuel rockets.

2. A preliminary design study has been completed of a launching ramp for use with dry fuel booster rockets.

3. The study of electric launchers was extended.

(e) Mathematics

1. Studies of homing with minimum fuel consumption have been carried out.

2. Calculation of craft and target trajectories during the homing stage have been completed.

3. Studies of homing systems without range information have been initiated.

(f) Propulsion

1. Ram jet performance studies using theoretically correct mixtures have been completed and a memorandum will be issued.

2. Pulse jet performance calculations have been completed, and a memorandum is being issued.

3. Apparatus for the study of factors affecting the speed of flame propagation has been constructed.

(g) Research Techniques

1. A schlieren system for the supersonic wind tunnel has been designed and is under construction.

2. A literature study has been completed of the presence of hydrogen in the upper atmosphere.

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(h) Members of the staff visited the organizations listed below:

Activity Visited	Subjects Discussed
Aberdeen Proving Ground, Aberdeen, Md.	Schlieren apparatus in use at Aberdeen.
Princeton University, Princeton, N. J.	Interferometer methods of density measurements in supersonic wind tunnels. Interferometer construction.
General Electric Company, Schenectady, New York	Rocket testing facilities. Developments in rocket fuels.
Cambridge Field Station, Watson Laboratories	Infra-red tests at high altitudes
Massachusetts Institute of Technology, Cambridge, Mass.	Computers and general guidance considerations.
Bell Telephone Laboratories New York, New York	Computers and general guidance considerations.
Northwestern University, Evanston, Illinois	Infra-red developments.
Air Materiel Command Wright Field, Ohio	Propulsion system.
White Sands Proving Ground, New Mexico	Rocket tracking methods.
Ram Jet Conference Aeronautical Engine Research Laboratory of the NACA Cleveland, Ohio	Various papers which were presented on subjects concerned with ram jets.

(i) Visits from Other Activities. Personnel from the following organizations visited the contractor:

Visiting Group	Subjects Discussed
Air Materiel Command Wright Field, Ohio	General guidance problems.
Northrop Aviation Corporation Los Angeles, California	Target trajectories. Guidance methods and countermeasures.

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Douglas Aircraft Corporation Telemetering systems.
Santa Monica, California

(j) Conclusions Drawn from Visits and Conferences:

1. The schlieren system in use at Aberdeen is very similar to the design proposed for the University of Michigan wind tunnel. Bonding plastics should be investigated in connection with mounting test section windows.

2. The cost of an interferometer with a 16 inch field will be prohibitive for this project. If interferometric measurements of supersonic flow about models are desired, a smaller test section should be built so that an interferometer with smaller field can cover the entire test section or the field in a larger test section should be scanned with a smaller interferometer.

3. It may be possible to develop infra-red cells with maximum response peaks at longer wavelengths than those now available. This would reduce the response to sky background, and increase the sensitivity to radiation from the target. Such cells, when used with small aperture and high scanning speed, would permit the design of early warning equipment with maximum ranges up to perhaps 250 miles.

4. Based on the tracking systems in use at White Sands, it will probably be advantageous to use a continuous lobing system rather than lobe-switching or scanning. Maximum ranges so far attained tracking V-2 rockets are of the order of 100 miles.

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III AERODYNAMICS

Performance Studies

Preliminary performance studies indicate the possibility of constructing a single stage liquid rocket capable of reaching an altitude of 500,000 feet and a range of 100 miles provided the specific impulse is of the order of 250 sec. or greater. The use of a continuously operating rocket burner as a means of control and guidance will present serious weight problems. These studies indicate that:

(a) It would be desirable to make major corrections to the flight path as near the start of the flight as possible.

(b) Drag effects are of second order magnitude.

(c) In order to have a reasonably small elapsed time for the ascent it would be desirable for the craft to have a vertical velocity component of 1000 to 2000 ft/sec at the interception altitude.

Studies are nearing completion of the effects of different trajectories and the effect of dry rocket boost on the performance of the craft. As an illustration of the type of study being conducted, fig. (1) shows the velocity-altitude relationships for a vertically ascending rocket operating at constant thrust. The radial curves represent burning rates expressed as fractional gross weight change per unit time, the transverse curves show fuel burned as a fraction of gross weight, and the feathered curve represents conditions at which the rocket engine may be cut off. The missile will then coast to the design altitude (in this case, 100 miles).

Dynamic stability and controllability studies are being continued for a missile outside the earth's atmosphere, the controlling moments arising from jet rudders.

Skin Temperatures at High Speeds

At high speeds, the direction and quantity of heat flow from a fluid to a solid boundary is altered by the generation of frictional heat in the boundary layer. Fig.(2)represents the boundary layer temperatures that may be expected at various Mach numbers and altitudes.

The skin temperature of the missile approaches asymptotically the value at which the heat absorbed from the boundary layer equals the heat radiated to space. An estimation of the skin temperatures has been made by use of Eber's empirical formula for the heat transfer to a cone. From fig. (3) the time necessary to raise the skin temperature to 3/4 ($T_{\text{boundary layer}} - T_{\text{Ambient air}}$) for various Mach numbers, altitude, and skin thicknesses may be computed. The chart is drawn for steel.

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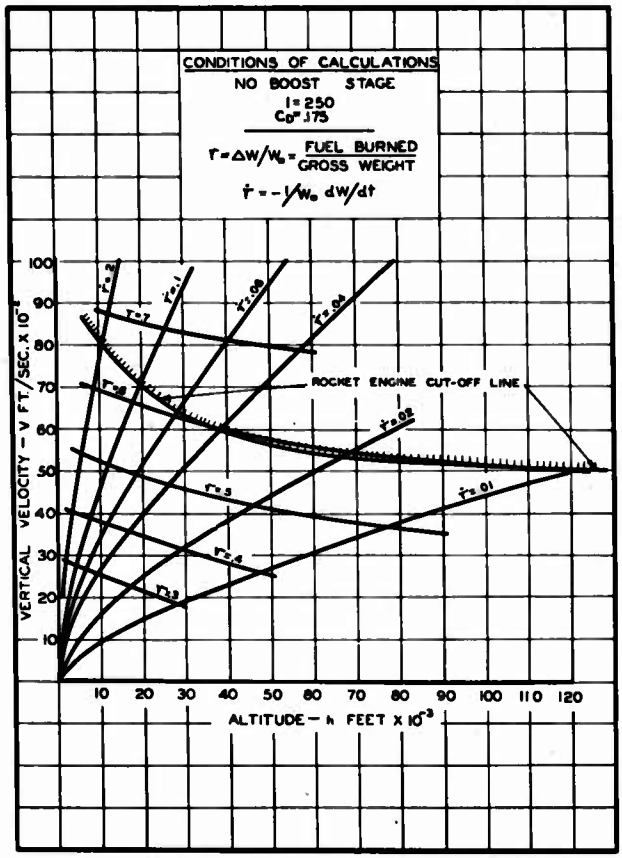

Fig. (1)

ROCKET PERFORMANCE IN VERTICAL FLIGHT

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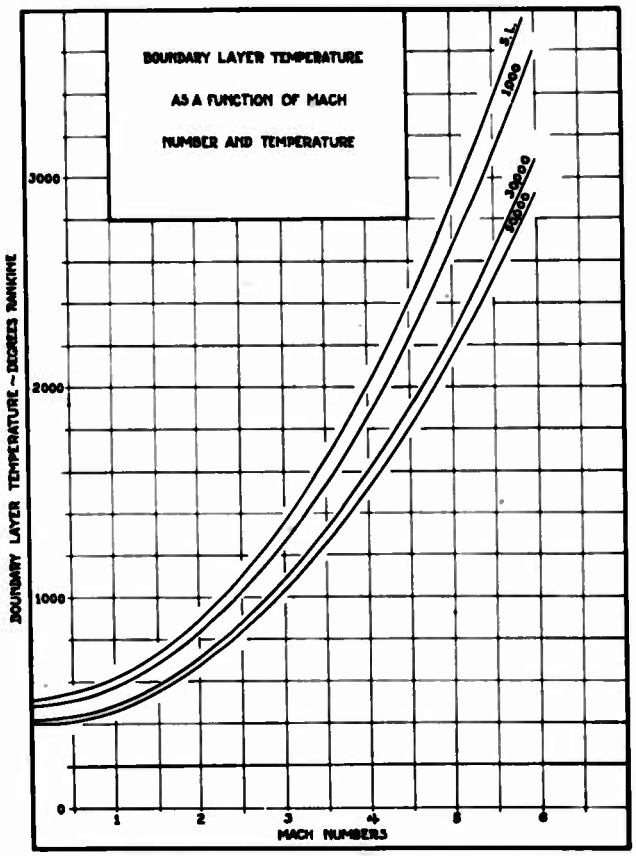

Fig. (2)

BOUNDARY LAYER TEMPERATURE

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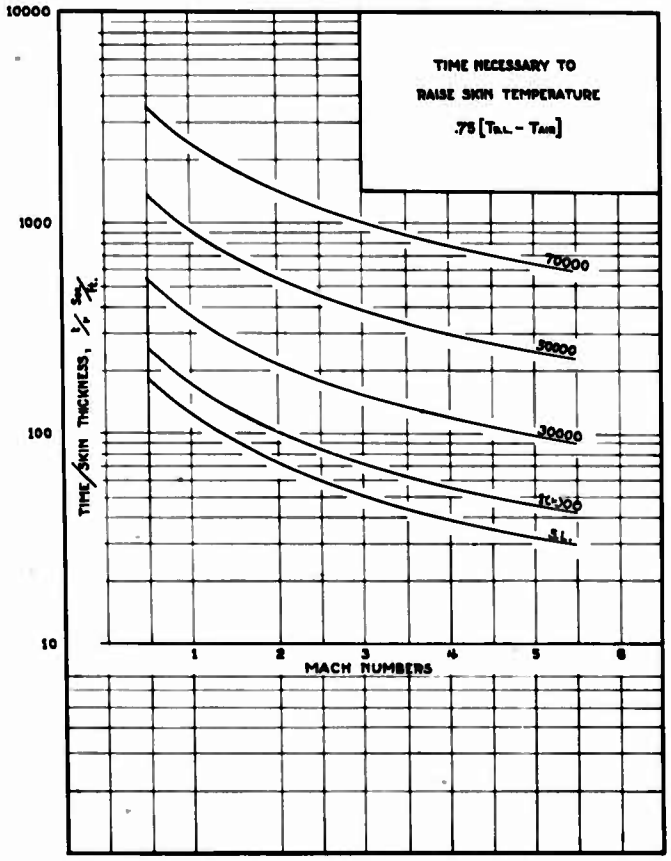

Fig. (3)

SKIN TEMPERATURE

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Compressible Flow Relations with Variable Specific Heat

The rise in the specific heats of air with temperature causes a large variation in the factor $\gamma - 1$ as may be seen from fig. (4). γ represents the ratio of the specific heat at constant pressure to the specific heat at constant volume.

As a result, it is necessary to reconsider all the standard relations in the light of a variable γ. It has been found that:

(a) For Mach number variations between zero and unity, the change in $(\gamma - 1)$ will not be greater than 1%. Therefore, if the numerical value of γ at stagnation temperature of the air is used, the standard relations will yield results that have negligible error.

(b) For Mach numbers greater than 3, the ratios of free stream to stagnation values should be computed from a set of air tables. For example, the use of the standard relations at a Mach number of 6 leads to an error in the ratio of static to stagnation pressure of 2%.

(c) The standard relations across a normal shock wave are also in error by a large amount above a Mach number of 3. As an example, at a Mach number of 6, the velocity downstream of a normal shock as computed by the standard formula is in error by 48%. On fig. (5) a chart is drawn from which the properties downstream of a normal shock may be computed. The chart takes into account the variation in specific heats of air with temperature.

Diffusers

For both oblique and normal shock diffusers, efficiency requires that subsonic diffusion begin from a Mach number near unity. Losses due to viscosity effects in high speed diffusers are known to be quite high. An analysis of the skin friction losses in a diffuser designed to reduce the stream Mach number from 0.9 to 0.2 indicates that skin friction may be only a small part of the losses resulting from the viscosity of the fluid. This suggests that separation may be a large contributing factor, and that boundary layer control may be an effective and practical device for increasing high speed subsonic diffuser efficiency.

Supersonic Wind Tunnel

The design of the supersonic wind tunnel has been completed, and a contract has been let for the overall installation. Fig. (6) shows a plan and section of the proposed tunnel. Dry air will be stored in the air bag and, upon actuation of the butterfly valve, will be drawn through the test section into the vacuum chamber, which consists of nine tanks and a manifold system. Maximum runs of approximately 15 seconds at Mach numbers between 1.4 and 5.0 appear possible, with about 10 to 15 minutes minimum elapsed time between runs.

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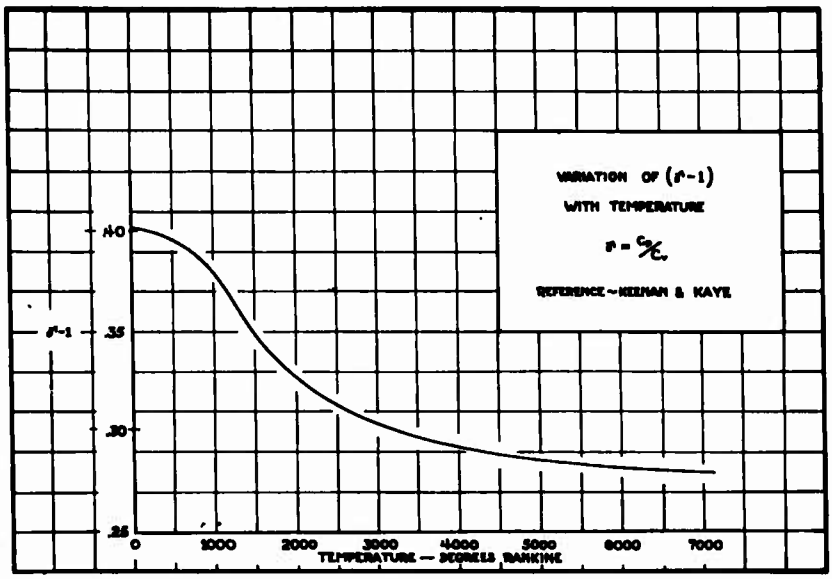

Fig. (4)

VARIATION OF (γ - 1) WITH TEMPERATURE

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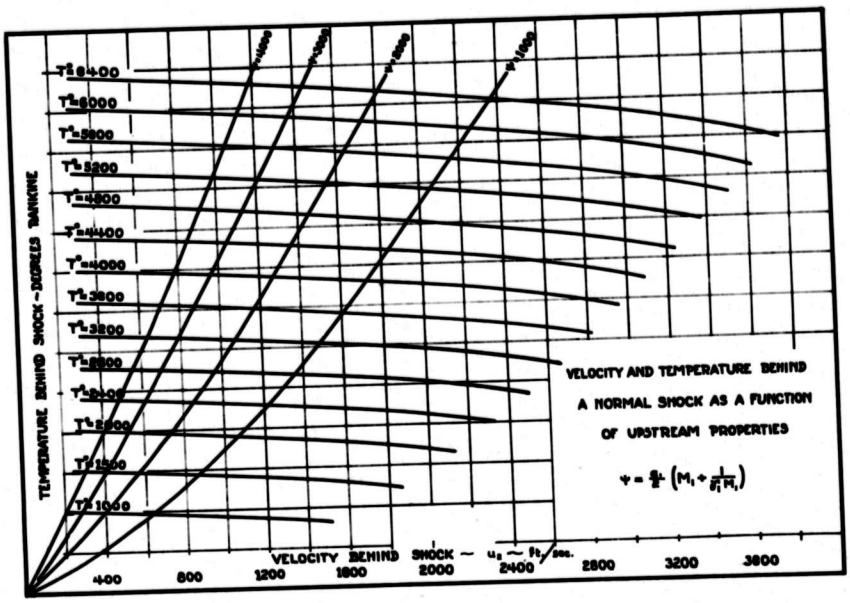

Fig. (5)

PROPERTIES DOWNSTREAM FROM A NORMAL

SHOCK AT HIGH MACH NUMBER

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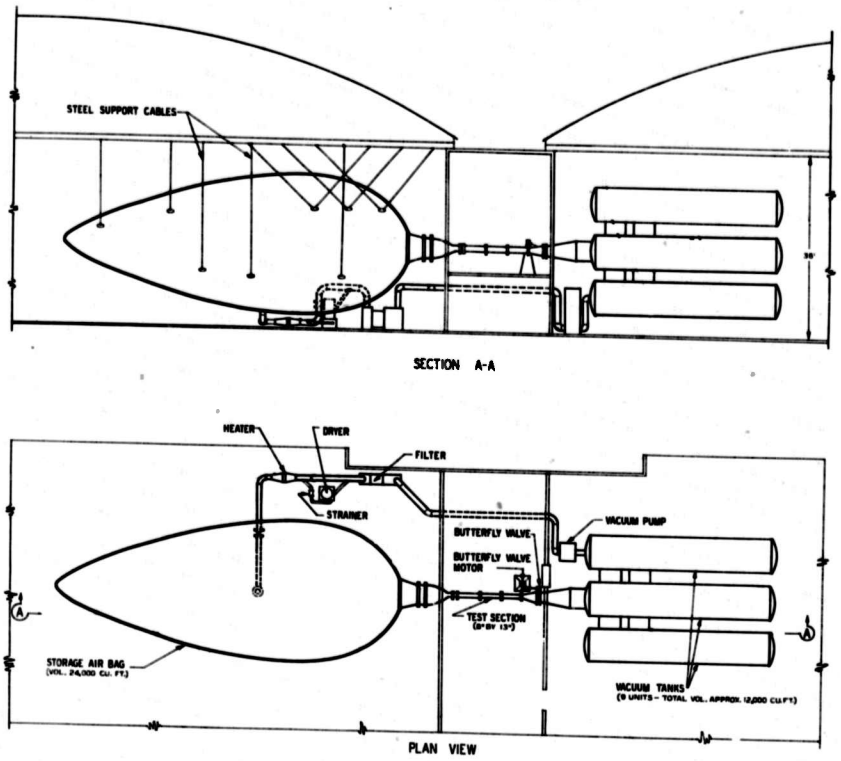

Fig. (6)

PLAN AND SECTION OF SUPERSONIC WIND TUNNEL

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Experiments with plastar nozzles are continuing, and a 1/4 scale model has been cast. Results indicate the necessity for further experimentation to improve the method of mold construction. The balance system details have been started, and a mock up will be constructed in the near future.

The vacuum tanks are war surplus tank cars originally constructed to withstand internal pressure. An analysis of the buckling strength of a tank under external pressure by the method of S. Timoshenko, "Theory of Elastic Stability", indicated that the tank heads and domes and the lower portion of the cylindrical tank surface possessed adequate strength. The upper portion of the tank is of thinner material and, if unstiffened, is considerably under strength. However, assuming the domes to act as stiffeners and reduce the effective length of the curved cylindrical panels, the calculated critical buckling pressure is approximately 15 p.s.i., which is marginal, as the evacuated tank will be subjected to atmospheric pressure. An additional tank was therefore procured for test purposes, and under partial evacuation, it failed at a pressure differential of 14.4 p.s.i. Fig. (7) is a photograph of the buckled tank. The buckling pattern consists of one half wave longitudinally and six half waves circumferentially, which is in accordance with the theory. In order to determine the most economical method of reinforcement, a series of tests is planned on small models of the tank under external pressure. In order to permit the use of reasonable model wall thicknesses, it was decided to utilize magnesium alloy, relating the dimensions and thickness of the model to those of the full scale tank so that failure of the unreinforced model will take place at the same value of external pressure as the full scale tank.

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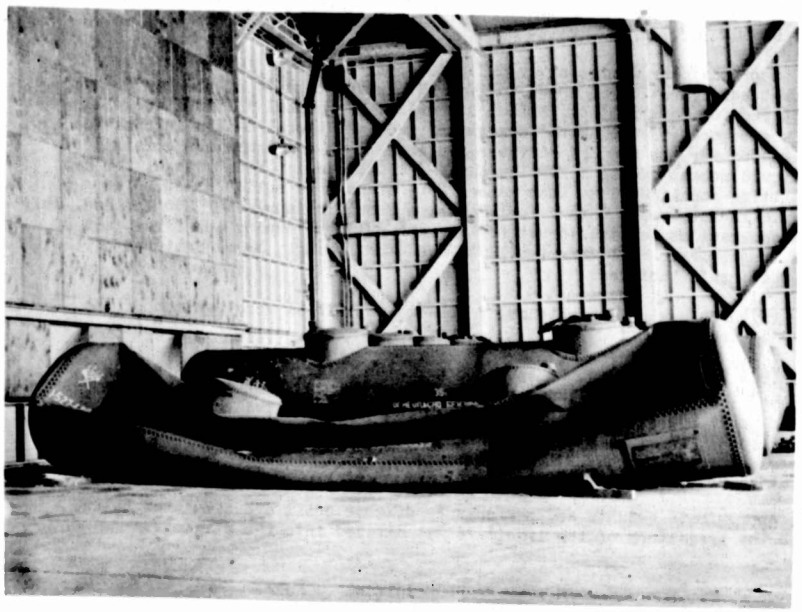

Fig. (7)

PHOTOGRAPH OF VACUUM TANK AFTER FAILURE

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IV DESIGN

A preliminary design study has been completed which indicates that a rocket configuration as shown in fig. (8) may be capable of the performance required for this project, although critical mechanical difficulties will be encountered in the actual design and much additional design information is needed for the ram jet diffuser section. This configuration consists of a liquid rocket having a 200 lb. warhead and a ram jet boost stage, the ram jet being accelerated to Mach number 2 by means of a solid rocket. The liquid rocket, which uses a fuel having a specific impulse of 250 lb. sec./lb., will operate at partial thrust for command guidance during the first part of its trajectory. Full thrust will be used for homing. Novel features of the overall craft include:

(a) The use of a single solid rocket for initial acceleration of the ram jet.

(b) Utilization of the space between the outer surface of the liquid rocket and the inner surface of the forward portion of the ram jet as the diffuser, with these surfaces so profiled that relative displacement will vary the diffuser ratio.

(c) An adjustable ram jet burner nozzle.

Approximate weights and performance of this craft are tabulated below, with the trajectory of the liquid rocket divided into two stages:

Stage	Propellant	Max. Thrust (lb.)	Time (sec)	Initial Weight (lb.)	Fuel Weight (lb.)	V_{max} (ft/sec)	Max Alt. (ft)
1	Solid Rocket	189,500	4.4	15,000	4,500	2200	4,400
2	Ram Jet	30,000	23	9,000	1,000	3250	67,000
3	Liquid Rocket	3,750	120	3,300	1,800	6000	500,000
4	Liquid Rocket	15,000	6	1,500	400	—	———

Design studies now in progress include a single stage, self-launched, liquid rocket, operating at full thrust up to approximately 60,000 feet with partial thrust above this elevation for command guidance and homing. A multi-stage liquid rocket design study is also underway with each unit operating continuously at full thrust during its portion of the trajectory.

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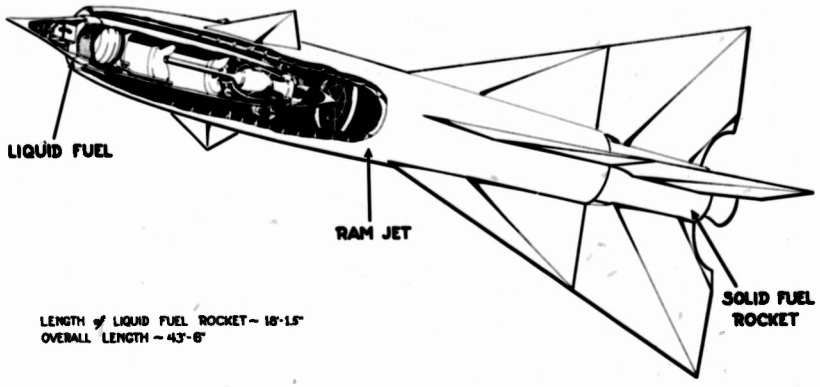

Fig. (8)

CONFIGURATION OF DESIGN STUDY NO. 1

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The German X-4 guided missile has been returned to the Applied Physics Laboratory, Johns Hopkins University. Other laboratories have analyzed all components of this missile with the exception of the burner. In an effort to determine the type of construction and principle of operation of the burner, several X-ray photographs were taken. Fig. (9) is a typical X-ray. From these photographs the schematic drawing, fig. (10) was prepared. This shows that the burner consists of three concentric shells assembled by welds, with the "Salbei" (nitric acid) entering the outer chamber and flowing to the aft end of the burner where it enters the inner circulating chamber and flows forward, constrained to follow a helical path for effective cooling, to the base of the burner, where it combines with the "Tonka" (xylidine-triethylamine) in the burner chamber.

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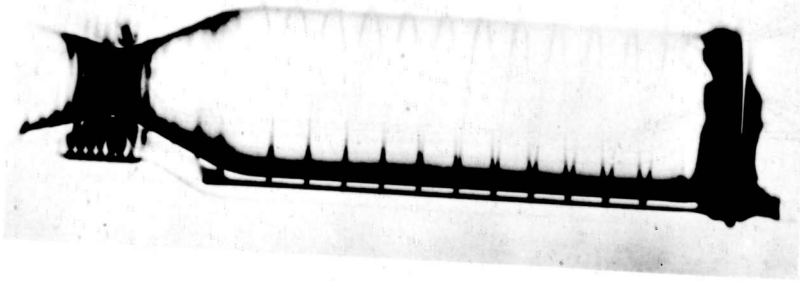

Fig. (9)

X-RAY PHOTOGRAPH OF GERMAN X-4 ROCKET BURNER

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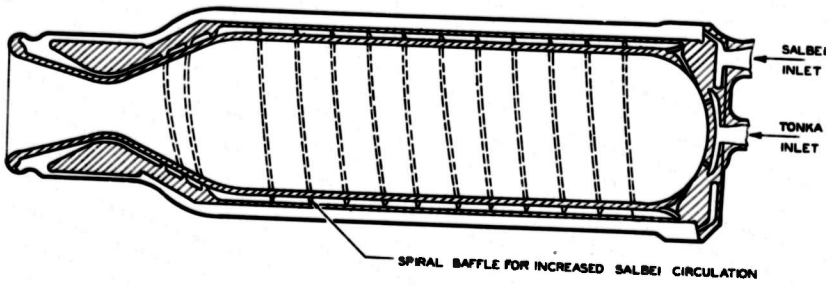

Fig. (10)

SCHEMATIC DRAWING OF GERMAN ROCKET BURNER

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V GUIDANCE

The design and development of early warning and tracking equipment is not considered a part of this project. However, tracking equipment will be required during test phases of the project, and the interrelationship existing between early warning, tracking, command-guidance, and homing justifies a study of early warning and tracking problems.

Studies of proposed long range missile trajectories indicate that extremely high velocities or long atmospheric glide paths will be developed which appear to place these targets outside the scope of this project. Therefore, attention is being directed primarily to targets with ranges of 750 miles or less, and fig. (11) shows approximate trajectories of targets with ranges of 200, 500, and 750 miles. These trajectories are being studied to determine optimum locations for target early warning and tracking systems and to determine the performance requirements of these equipments. Indications are that early warning equipment will need a range of the order of 300 miles.

The possibility of using infra-red devices for early warning is being investigated. Atmospheric attenuation limits the range of ground-located devices, but this factor would be greatly reduced if the equipment could be carried in an aircraft at an altitude of about ten miles. Infra-red radiation from the sky background would probably remain troublesome, but by reducing the aperture of the device to 1/2 degree, it is believed that background effects could be sufficiently reduced to make possible a range of 100 miles even during daylight hours. There are indications that it may be possible to develop infra-red cells with the maximum response peak at longer wavelengths, which would reduce the background response and increase the sensitivity to radiation from the target. The use of small apertures calls for extremely high scanning speed, but it is believed possible to develop such optical scanners and thereby increase the range to about 300 miles. Ranges were calculated assuming a V-2 type target at a temperature of 300°C.

A report on tracking systems is being prepared which covers existing tracking methods as well as tracking requirements for this project and possible methods of meeting these requirements. Except during the final stages of interception, the target and craft will be widely separated, requiring separate tracking equipments. The craft tracking equipment will be required to track continuously from a minimum range of one or two miles to a maximum range of 150-200 miles, and tracking aids such as a responder beacon may be mounted in the craft. The target tracking equipment will be required to track continuously from a maximum range, perhaps as much as 250 miles to a minimum range of approximately 100 miles, and the target will not possess tracking aids.

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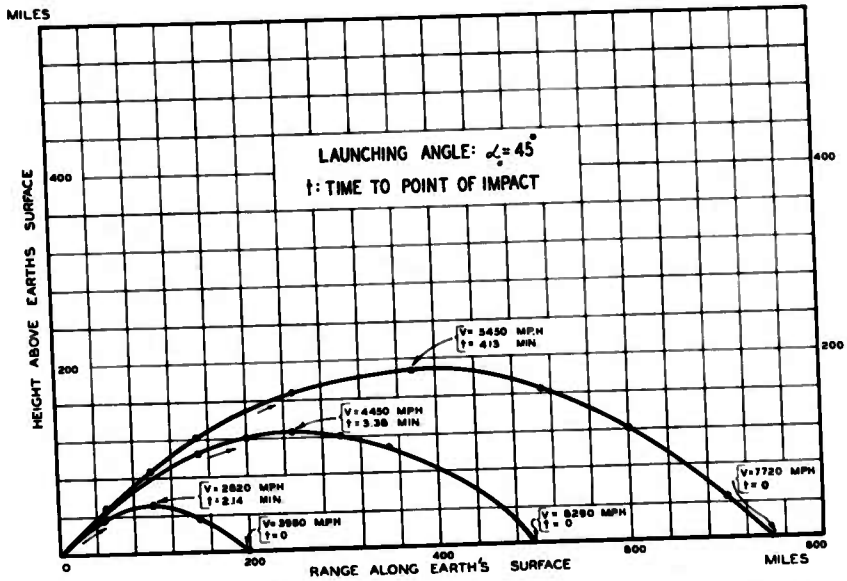

Fig. (11)

POSSIBLE TARGET TRAJECTORIES

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Maximum ranges so far attained at White Sands on V-2 rockets with responder beacons are of the order of 100 miles, which is not greatly less than the required craft tracking range, and it is anticipated that the desired range can be achieved without great difficulty. However, the design of target tracking equipment, where no responder beacon can be used and ranges perhaps up to 250 miles are required, will require much additional work.

The general study of craft-borne guidance equipment has continued and the block diagram of fig. (12) represents one of several possible schemes of operation. This block diagram utilizes the ground illumination of target homing principle, this method requiring less development than others. Briefly the equipment consists of:

(a) A command receiver operating from modulation on the craft tracking beam. This consists of two channels giving proportional directions to the craft for elevation and azimuth manouvers, and a third channel which for the first minute of operation gives roll instructions and thereafter instructions regarding warhead arming, release of craft from command guidance, and if necessary, self destruction.

(b) A beacon which operates to increase the effective range of the craft tracking radar. This beacon is modulated during the first minute of flight by a gyro-compass such that the roll angle of the craft in its initial vertical flight can be controlled by command from the ground on a servo system basis. After the first minute of flight, the telemetering aspect is transferred to reporting to the command station the instant the homing device locks on target. The beacon also incorporates an IFF feature, such that if more than one craft is in the air at one time, they will not home upon each other.

(c) A homing device, actuated by the reflection from the target of the target tracking radar beam. The operation of this homing device is essentially the same as that proposed by Dr. R. M. Page of NRL in Bumblebee Report No. 37. The major difference arises from the fact that the craft does not carry its own radar transmitter, but utilizes that of a ground-based radar. The range information received from such a system is then more approximate than is customary and varies with the relative positions of target, craft, target tracking radar, and synchronised craft tracking radar. This device, utilising continuous lobe comparison, operates to maintain its antenna system on a line of sight with the target. Through the incoporation of radio frequency bridges, and a unique method of comparison of signals, there results a null system for servo operation with an indication of operation when the antenna system is properly oriented.

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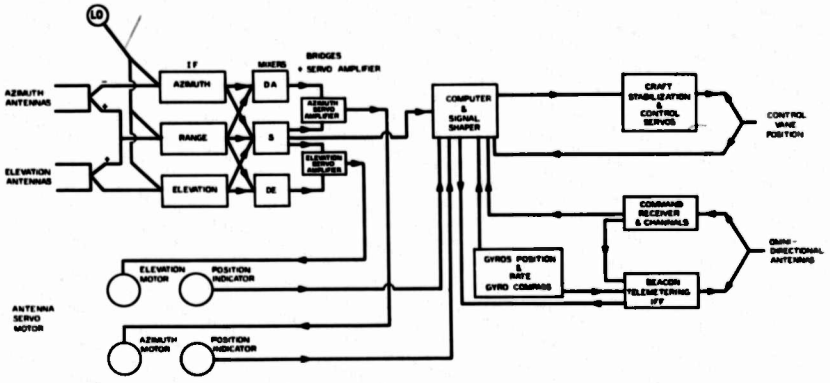

Fig. (12)

TENTATIVE BLOCK DIAGRAM OF AIR BORNE GUIDANCE EQUIPMENT

(d) A computer which received information during the homing period from the angles and rates of change of angles between the craft axes and the antenna system, the craft axes and a gyro-stabilized platform, and the neutral positions and instantaneous positions of the control vanes. Using this information and the range and rate of range change information received from the homing unit and the known parameters of the craft, the computer calculates continuously the course to be followed and conveys this information to the craft's controls.

(e) A mechanical memory and sense system comprising gyroscopically operated devices and accelerometers to supply information of the positions and rates of change of position of the craft's axes with respect to their initial position.

Design of the command receiver has been started, and the necessary modifications to an SCR 584, for use as a command transmitter and craft tracking radar for initial experimental purposes, are being determined. Because of the extended maximum range and low effective PRF rate of the tracking radar, the initial receiver design will incoporate pulse-time modulation channels.

Because of the inadequacy for this project of present development in homing apparatus, the desirability of pursuing further development is indicated. This should probably cover the following four types of equipment:

(a) Pulsed microwave radar.

(b) CW microwave radar.

(c) Infra-red homing equipment.

(d) Ground illumination of the target homing equipment.

Theoretical work involving the use of infra-red radiation from the target as a means of homing has continued. It now appears that the use of infra-red for this purpose, utilising existing developments in the way of sensitive devices and optical materials, is marginal. This conclusion depends to a considerable extent upon the present inexactness of knowledge of parameters, notably the background noise level to be expected at advanced altitudes and the temperature range of possible targets. It is to be noted that in the homing period, the target has had considerable cooling time over and above that existing at initial detection by a possible early warning system. A short-time study to clarify this situation, insofar as is at present feasible, has been inaugurated.

Assessment of present pulsed microwave airborne radar and its possible development into homing units is continuing.

Work on the microwave test laboratory has continued.

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VI LAUNCHING

Studies have been initiated of possible methods of increasing the ratio of fuel weight to structural weight of dry fuel rockets. Current fuel/structure weight ratios approximate unity, although designs now being prepared by other organizations have ratios as high as 2. By the use of light alloys, or alloy steels which are capable of maintaining high tensile strength at elevated temperatures, it is hoped that the fuel/structure weight ratio may be increased very substantially.

A booster rocket preliminary design study was completed as a portion of the design study of a ram jet - rocket combination (see fig. (8)). This rocket is a single dry fuel rocket 36 inches in diameter. A ratio of fuel weight to structural weights of 2.9 is considered possible by the use of an alloy steel, which exhibits good tensile strength at high temperatures.

A study is being conducted, leading to a preliminary design of a launching ramp suitable for a missile similar to that shown in fig. (8). The launcher is designed to received the missile in a horizontal position and rotate it to a vertical or near vertical position for firing, with the entire launcher adjustable in azimuth. Details of the elevation and train mechanism and the power requirements of these mechanisms are being worked out.

Further studies are in progress to decrease launcher size and weight, to adapt the design to a portable mount, and to increase ease of handling and speed of firing. The goal is to make all operations from the removal of the missile from storage to its actual firing as nearly automatic as possible.

VII MATHEMATICS

Computing work on homingwith a minimum fuel consumption has been carried out in order to obtain information on the theoretical minimum fuel-to-craft weight ratio that is required in the homing stage. Fig. (13) is an example of one of several types of results obtained. In this diagram the abscissa β is the angular error at the beginning of homing, that is, the angle between the line of sight and the direction of the craft velocity relative to the target. The ordinate W* gives the minimum fuel-to-craft weight ratio required for the interception. (By weight of craft is meant the total weight of craft at the beginning of homing with the exclusion of weight of fuel.) The particular curve shown is based on the assumption of an initial craft-to-target distance of 50,000 ft., and initial relative velocity of 10,000 ft/sec, a specific impulse of 165 seconds and maximum acceleration during homing of 300 g. The homing time which corresponds to the calculated minimum fuel consumption increases with β from 5 to 50 seconds; it equals 50 seconds along the broken line of the diagram. For instance, with an initial angular error of 20° the theoretical fuel consumption equals the weight of the craft (i.e., W* = 1) and the corresponding homing time is 6 seconds.

Diagrams for various values of the parameters affecting W* are available. Calculations of craft and target trajectories during the homing stage and optimum homing times have been completed.

The procedure followed in the foregoing analysis was based on the replacement of the variable inclination of the thrust by a constant average. The exact analysis which takes into account the possibility of a variable direction of thrust includes a problem of calculus of variations whose solution is being obtained.

Although the completed work concerns mainly the type of homing in which information of relative range and relative velocity must be available to the homing device, work is in progress on types of homing in which a reduced amount of information is sufficient for the interception. These latter studies may be of value for homing with infra-red guidance.

Studies on the pre-homing stage have been started and methods to deal with the dynamics of the flight through the lower regions of the atmosphere are being worked out. These methods include pertubation methods, successive approximation methods by means of quadratures, and the use of the existing tabulated functions such as Bessel functions, incomplete Gamma functions and Exponential integral.

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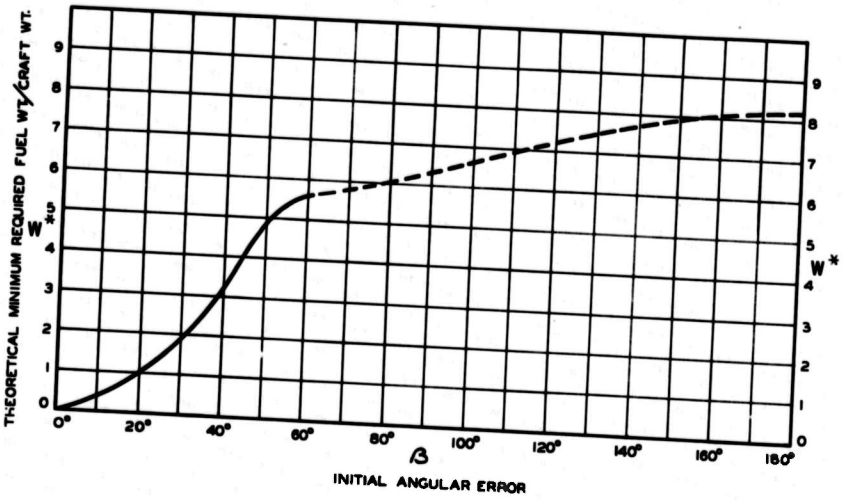

Fig. (13)

TYPICAL REQUIRED HOMING FUEL AS A FUNCTION OF INITIAL ANGULAR ERROR

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VIII PROPULSION

Estimates have been made of the performance of ram jets at constant altitude and variable Mach number as well as over vertical flight paths. Fig.(14) is a typical set of performance curves for a ram jet operating at an altitude of 40,000 feet. Fig. (15) shows a comparison between the altitude/time relationships of the following:

(a) A ram jet with a completely variable diffuser.

(b) A liquid rocket with characteristics similar to those of the V-2 rocket.

(c) A ram jet - rocket combination, which has much greater weight than (a) above.

A study of pulse jet performance using an ideal analysis of the pulse jet cycle is nearing completion. The results permit calculation of relative performance with changes of speed and fuel/air ratio. Test data indicate relatively close approximation to calculated results.

The evaluation of a turbo jet power plant for high flight Mach numbers has been initiated, and is approximately 25% completed.

Apparatus has been designed for investigating the factors affecting the speed of flame propagation in combustible mixtures. This apparatus, which is shown schematically in fig. (16), is now ready for operation. It consists essentially of a blower and surge chamber for air supply with minimum pressure fluctuations, an air heater and humidifier, a mixing chamber, where the conditioned air is mixed with gas supplied from a pressure tank through a reducing valve, a water cooled burner, and the requisite apparatus for measuring pressures, temperatures, and rates of flow of air and gas. A flash-back trap is provided to prevent damage to the instrumentation.

Studies have been initiated of equilibrium temperatures of ram jet burners at high altitudes and velocities for the purpose of determining cooling requirements.

A study of German literature on existing rocket fuels has been initiated, and a chemistry group has been formed to assist in fuel studies. Data have been collected on the products of combustion and computations are proceeding toward construction of enthalpy-entropy diagram for the 3:1 fuel combination of red fuming nitric acid and aniline.

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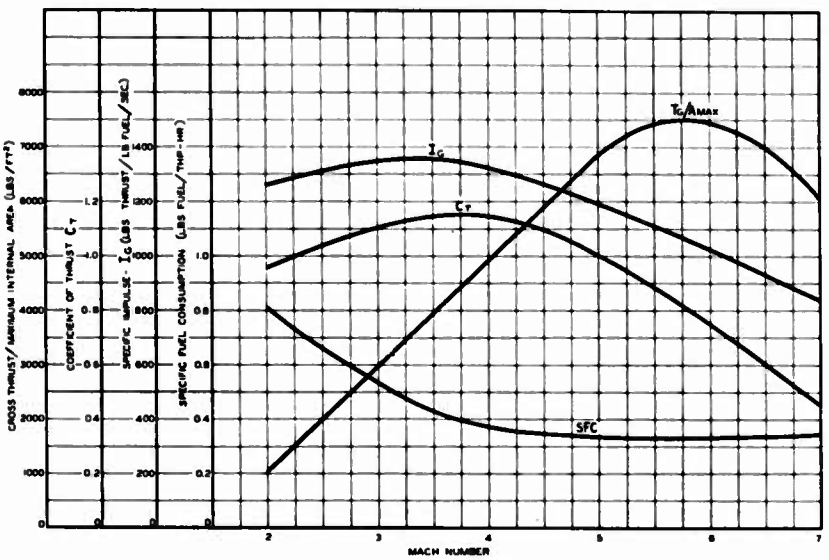

Fig. (14)

RAM JET PERFORMANCE AS A FUNCTION OF MACH NUMBER AT CONSTANT ALTITUDE

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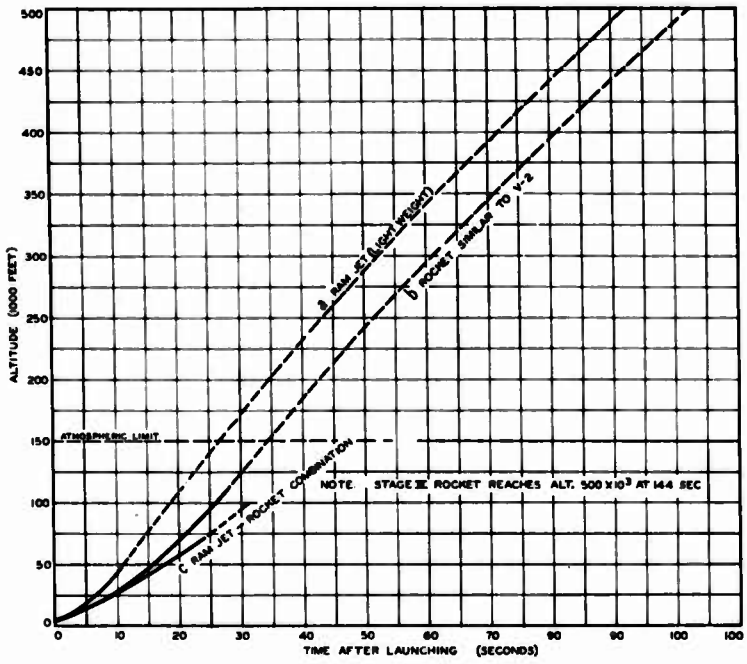

Fig. (15)

ALTITUDE AS A FUNCTION OF TIME FOR A ROCKET-RAM JET COMBINATION

SECRET

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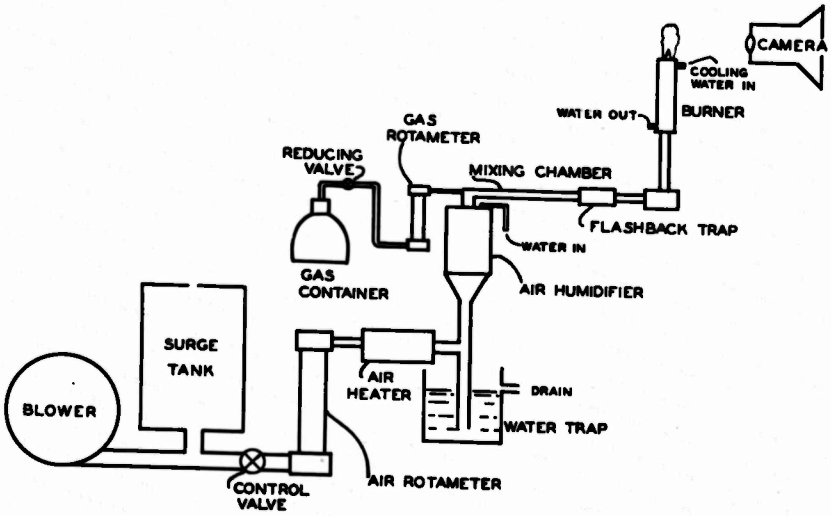

Fig. (16)

SCHEMATIC DIAGRAM OF FLAME SPEED EQUIPMENT

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IX RESEARCH TECHNIQUES

Equipment and facilities are being assembled for the construction, evaluation, and operation of telemetering equipment for flight experimentation in connection with aerodynamics, propulsion, and electronic systems. No equipment is being provided for external observations, as it is assumed that equipment for radar tracking and theodolite observations will be available at the testing site or sites.

The existence of a hydrogen concentration in the upper atmosphere which might be used as fuel has been the basis for some speculation. From a study of existing literature it is concluded that although direct temperature measurements and sampling of the atmosphere are limited to the present 12 mile ceilings of sounding balloons, certain inferences regarding composition, temperature and density of the atmosphere above this level can be made from observations of the anomalous propagation of sound, spectroscopic measurements of ozone, atmospheric tides, the ionosphere, and the aurora. These observations indicate little free hydrogen (certainly less than 1% by volume) at any level in the earth's atmosphere.

A schlieren and shadowgraph system has been designed for the supersonic wind tunnel, and all components have been obtained or are on order. Fig. (17) is an optical diagram of the proposed system. The two pyrex glass parabolic mirrors, which are 16 inches in diameter are ground to within 1/10 of the wavelength of sodium light. A flash unit is being built for the mercury lamp which will produce a flash with a duration of about 4 microseconds, so that sharp photographs may be obtained in spite of unsteady or oscillatory conditions in the air flow.

Interferometer methods of measuring wind tunnel densities were investigated, and it was concluded that an interferometer comparable in size to the test section of the supersonic wind tunnel would be prohibitively expensive. If an interferometer is to be used, a much smaller test section must be provided. An investigation is being made of other methods of density measurement, including the introduction of small quantities of gases other than air into the circulating air of the tunnel.

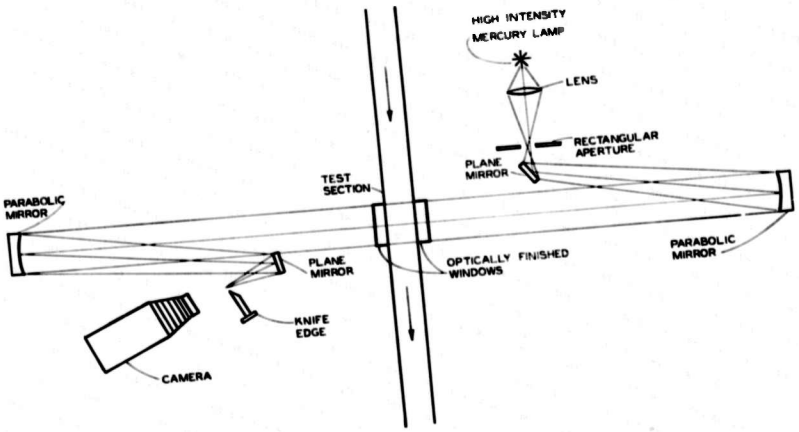

Fig. (17)

SCHEMATIC DIAGRAM OF SCHLIEREN APPARATUS

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X PROGRAM PLANNED FOR NEXT PERIOD (1 DECEMBER 1946 - 1 FEBRUARY 1947)

(a) Aerodynamics

1. Trajectory studies and stability and controllability studies will be continued.

2. Installation of equipment for the supersonic wind tunnel will be started.

(b) Design

1. Remaining details of the single stage liquid rocket preliminary design study will be completed.

2. The preliminary design study of a multi-stage liquid rocket will be completed.

(c) Guidance

1. The Guidance Systems Planning Report will be completed.

2. The study and report on target and craft tracking will be completed.

3. The study of early warning requirements will continue.

4. A theoretical study of the effectiveness of rockets as radar targets will be initiated.

5. Work will be started on an investigation of the overall performance of the guidance and control systems.

(d) Launching

1. Further studies will be made of methods of increasing the ratio of dry rocket fuel weight to structure weight.

2. Studies of the electric launcher will be continued.

3. Power requirements of launching ramp operating mechanisms will be determined.

4. Studies will be initiated of automatic handling and launching systems.

(e) Mathematics

1. A memorandum will be issued showing the results of homing studies with minimum fuel consumption.

2. Studies will be continued of homing methods without range information.

3. Studies of the pre-homing stage will be continued.

4. The study of trajectories of long range rocket targets will be started.

(f) Propulsion

1. A memorandum will be issued giving the results of the ram jet performance studies with constant fuel/air ratios.

2. Studies will be completed of ram jet performance with variable diffuser and fuel/air ratios.

3. Turbo-jet performance studies will be completed.

4. The flame speed apparatus will be placed in operation, and studies will be initiated of factors affecting the speed of flame propagation.

5. Studies of ram jet cooling requirements will be continued.

(g) Research Techniques

1. The schlieren apparatus for the supersonic wind tunnel will be assembled and tests will be initiated.

2. The telemeter laboratory will continue to be developed and detailed plans for the flight testing of design components will be submitted.

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XI REPORTS AND MEMORANDA

The following reports have been issued to date:

UMR-1 Progress Report No. 1 (1 April - 1 June 1946)

UMR-2 Progress Report No. 2 (1 June - 1 August 1946)

UMR-3 Progress Report No. 3 (1 August - 1 October 1946)

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13453

ATI [illegible]

US Classification: Secr.

OA No.: [illegible]-4

TITLE: Progress Report No. 4, Project LD-794 - Period 1 October - 1 December 1948 - Project "Wizard"

AUTHOR(S):

OA:

Foreign Title:

Previously Cataloged Under No.:

Translation No.:

Subject Division:

Section:

10

MCI—Form No. 89B WF-L-23 MAY 49 200M
Library Card

TITLE: Project Wizard, Progress Report No. 4

AUTHOR(S): Conlon, E. W. Corrected Copy (1)

ORIGINATING AGENCY: Univ. of Michigan, Dept. of Engin. Research, Ann Arbor

PUBLISHED BY: (Not known)

ATI- 661

REVISION (None)

ORIG. AGENCY NO. UMR-4

PUBLISHING AGENCY NO.

DATE	DOC. CLASS.	COUNTRY	LANGUAGE	PAGES	ILLUSTRATIONS
Dec'46	[redacted]	U.S.	Eng.	42	photos, tables, diagrs, graphs

(OVER)

ABSTRACT:

This report pertains to the performance and design studies of single stage and multi-stage liquid rockets and to liquid rocket with ramjet boost. Applicability of infrared equipment for early warning and homing is studied; methods of increasing possible ratio of fuel weight to structural weight of dry fuel rocket are worked out. Homing with minimum fuel consumption and calculation of craft and target trajectories during homing stage have been completed. Ramjet and pulsejet performance calculations were finished. Apparatus for study of factors affecting speed of flame propagation has been constructed.

P 1948.1

A Liquid rocket propellants

DISTRIBUTION: Copies of this report obtainable from Air Documents Division; Attn: MCIDXD

DIVISION: Guided Missiles (1)

SECTION: Design and Description (12)

ATI SHEET NO.: S-1-12-33

SUBJECT HEADINGS: Missiles, Guided - Surface to air (63750); Missiles, Guided - Production - Design (63250); Wizard project (63250) (63750); Missiles - Homing guidance - Target seekers (62150); Missiles, Guided - Propulsion (63450)

U SCP-4. AUTH: DOD DIR 5200.10, 29 June 6

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS 88TH AIR BASE WING
WRIGHT-PATTERSON AIR FORCE BASE OHIO

12 May 2016

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3810 Communications Blvd
Wright-Patterson AFB OH 45433-7802

Defense Technical Information Center
Attn: Mr. Robert Stokes (DTIC-R)
8725 John J. Kingman Rd, Suite 0944
Ft Belvoir VA 22060-6218

Dear Mr. Stokes

This concerns the following Technical Reports:

The following records have been cleared for public release by HQ AFMC/PAX on 13 June 2007. The reviews were performed by the following Air Force organization: HQ AFMC/PAX. Therefore, the following records are now fully releasable to the public. See attachment 1.

Technical Report number: ADB816663
Technical Report Title: Project "Wizard" Progress Report No. 1
Technical Report Date: June 1, 1946
Previous classification/distribution code: Unclassified

Technical Report number: ADB816741
Technical Report Title: Project "Wizard" Progress Report No. 5
Technical Report Date: 1 December 1946 – 1 February 1947
Previous classification/distribution code: Unclassified

Subsequent to WPAFB FOIA Control Number 2016-02428-F, AFMC-2016-0019, the following record has been cleared for public release by HQ AFMC/PA on 4 April 2016. The review was performed by the following Air Force organization: HQ AFMC/HO. Therefore, the following record is now fully releasable to the public. See attachment 2.

Technical Report number: ADB817886
Technical Report Title: Project "Wizard" Progress Report No. 4
Technical Report Date: October 1 – December 1, 1946
Previous classification/distribution code: Unclassified

The following record is publicly available at the University of Michigan Library at the following link: https://deepblue.lib.umich.edu/bitstream/handle/2027.42/4989/bad5904.0001.001.txt?sequence=4&IsAllowed=y.

Technical Report number: ADB804022
Technical Report Title: External Memorandum Report No. 7, A Simplified Method of Calculating Ram-Jet Performance Applicable To High Mach Numbers
Technical Report Date: July 23, 1947
Previous classification/distribution code: Unclassified

Please let my point of contact know when the record is available to the public. Ms. Janet M. Caddell is the point of contact for this request and she can be reached at (937) 904-0884, e-mail Janet.Caddell@us.af.mil or the FOIA Office Main Line (937) 522-3095, e-mail wpafb.foia@us.af.mil.

Sincerely

DARRIN BOOHER, Civ, DAF
Freedom of Information Act Manager
Base Information Management Section
Knowledge Operations

Attachements:
1. AFMC/HO Memorandum, dated 11 June 2007
2. SAFPAOSP E-mail, dated 4 April 2016